

IN THE SPECIFICATION

Please amend paragraphs [0004], [0005], [0006], [0021], [0022], [0026], [0027], [0030], [0032], [0037], [0038], [0039], [0040], [0041], [0042], and the **Abstract** of the specification as indicated below:

[0004] Rear projection screens and light diffusers are characterized by their ambient light rejection, resolution, gain, and contrast as properties which are determined by the structure and composition of the component materials. For example, the gain which is a measure of the intensity of transmitted light as a function of the viewing angle, is determined primarily by the index of refraction of the spherical beads and the surrounding medium. Similarly, the ambient light rejection and contrast of the light filter are determined largely by the opacity optical absorption of the binder layer. The resolution of the screen is determined by the size of the beads used and how they pack together in the lens system.

[0005] However, the interdependence of certain optical properties and their dependence on the properties of component materials, limit optimization of the optical properties of basic refractive light filters. For example, if the opacity optical absorption of the binder layer is increased to enhance the ambient light rejection of the viewing surface, transmission of refracted image light through the binder layer in the transmission area of the bead will be reduced. In addition, the range of indices of refraction of available materials also limits the performance of such filters. Such interdependencies and material limitations hamper the performance of basic refractive filters.

[0006] A multi-layer light filter in accordance with the present invention includes a single layer of glass or resin beads supported in an opaque layer and an additional contiguous light-dispersing support or backing layer that exhibits asymmetrical or anisotropic light-dispersing properties along axes perpendicular to the direction of

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propagation. "Anisotropic" and "asymmetrical" are used interchangeably to have the same meaning for purposes of this disclosure. This structure of optical components enhances the diffusion dispersion or scattering of light along one axes, for example the horizontal axis, and without changing the diffusion dispersion or scattering of light along an orthogonal axis, for example, the vertical axis. Such a structure promotes wider viewing angles as viewed along one (i.e., the horizontal) axis from the light output side of the support layer. Such structure also leaves unchanged viewing angles, as viewed along the other (i.e., vertical) axis from the light output side of the support layer.

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[0021] Light 38 that is approximately collimated from an effectively distant image source (not shown) is incident on filter 10 at back surfaces 36 of beads 14 and back surface 19 of opaque binder layer 16 between the beads. These surfaces define an incident or image side of light filter 10. Outer surface 18 of the support layer 12 defines a front or viewing side of light filter 10 through which viewers observe the transmitted image light. Thus, light incident on beads 14 is refracted, transmitted through the beads 14 and the associated transmission apertures 34, and is asymmetrically dispersed to viewers through the support layer 12. Light 38 incident on the back surface 19 of the opaque binder layer 16 between beads 14 is absorbed to reduce transmission of this light through the filter assembly 10. Therefore, "opaque binder layer," "optical absorption binder layer," "light absorbing binder layer," "absorbing binder," and "absorbing layer" are used interchangeably to refer to layer 16 in this disclosure.

[0022] Referring now to FIG. 2, there is shown a diagram of the paths followed by refracted light rays 22, 24, 26, 28 incident on back surface 36 of bead 14 at various distances from optic axis 30. Substantially collimated light rays 22, 24, 26, 28 are refracted toward optic axis 30 by an angle Ψ that increases with the distance between a point of incidence 31 and optic axis 30. Angle Ψ also increases with the index of

refraction of beads 14. Refracted light rays 22, 24, 26, 28 are directed through transmission aperture 34, which includes the point of contact between bead 14 and support layer 12 as well as the surrounding area where intervening opaque binder layer 16 is too thin to absorb refracted light rays 22, 24, 26, 28. In contrast, non-collimated or refracted ray 29 strikes the front surface of bead 14 and tends to be refracted to outside of a transmission aperture 34 and ~~are~~ is absorbed by the opaque binder layer 16.

[0026] Ambient light rejection measures how well ambient light incident on the viewing surface of a light filter is absorbed or transmitted relative to the amount re-dispersed back toward the viewer. This property depends primarily on the reflectivity of the front surface of the support layer 18, the ~~epacity~~ optical absorption of binder layer 16 and the index of refraction of beads 14. Ambient light reflected into viewers' eyes from filter 10 can significantly impair the quality of an image by reducing the contrast.

[0027] In the filter assembly 10 illustrated in Figure 1, ambient light incident on the viewing surface 18 may be reflected at the interfaces between: a) the opaque binder layer 16 and support layer 12; b) the beads 14 and opaque binder layer 16; and c) beads 14 and air at incident surface 36. Of these, the air-bead interface may be most significant because the indices of refraction of support layer 12, opaque binder layer 16, and beads 14 can be made more nearly equal to minimize reflections from the first two interfaces. Ambient light rejection in the filter 10 of Figure 1 is affected by ~~epacity~~ optical absorption of binder layer 16. However, increasing the ~~epacity~~ optical absorption of binder layer 16 to improve ambient light rejection decreases the amount of image light transmitted through the transmission apertures 34 around the point of contact between beads 14 and support layer 12.

[0030] Referring now to Figure 6, there is shown another embodiment of a light filter 120 of the present invention comprising a single-layer array of light transmissive beads 14 structurally supported in an ~~epaque~~ absorbing binder layer 16 having a surface 19 through

which the beads 14 protrude to receive substantially collimated light 220 from an image source (not shown), and having a substantially flat interface surface 27 at which the beads 14 contact the support layer 12 of anisotropic dispersing properties. This allows transmission of the light 220 through a plurality of transmission apertures 34 and through the support layer 12 for viewing within different horizontal and vertical viewing angles. The beads 14 each have a radius about equal to a selected value R. The light filter 120 includes the transparent support layer 12 affixed to the surface 27 of the opaque absorbing binder layer 16, with the filter surface 18 oriented toward the viewer (not shown). The light filter 120 also includes an additional conformal layer of light transmissive material 128 disposed over the protruding beads 14 to a substantially uniform thickness between about 0.1R and 1.0R, where such thickness is measured normal to the spherical surfaces 36 of the beads 14. This conformal layer 128 can also cover the surface 19 of an opaque binder layer 16 between substantially contiguous beads 14.

[0032] The conformal layer 128 presents increased incident surface to incoming light 220 and functions as a preliminary stage of convergent refraction of light 220 from the image source (not shown) into the beads 14. This allows a greater portion of incident light to enter into the beads 14, and such light 220 so converged is incident on the protruding surfaces 36 of the beads 14 above the opaque absorbing layer 16 at angles that allow a greater percentage of the light 220 to enter the beads 14 and propagate into the transmission apertures 34 of the beads 14. Light emanating from the transmission apertures 34 is then asymmetrically or anisotropically dispersed by the support layer 12 for viewing through different horizontal and vertical viewing angles relative to the axis 11 that is normal to the viewing surface 18. Thus, a greater percentage of the light 220 striking the back surfaces 36 of the beads 14 is transmitted through the filter surface 18 than is typically feasible with conventional single-layer light filters, which have a typical transmittance ~~within the horizontal viewing angles to~~ of about 35 percent.

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[0037] The light filter 122 also includes a conformal layer 128 of light transmissive material disposed on the incident surfaces 36 of the beads 14 and surface 19 of an opaque absorbing binder layer 16. The additional conformal layer 128 defines a substantially spherical or parabolic lens 131 behind each bead 14, with local points or centers of curvature 342 disposed forward in the direction toward the source of incident light relative to the centers of curvature 340 of the beads 14. The layer 128 thus has a non-uniform thickness as measured normally to the spherical protruding surfaces 36 of the beads 14.

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[0038] The conformal layer 128 provides a preliminary stage of convergent refraction of the incident light 320, 322 into the beads 14. Further, it is believed that displacing the centers of curvature 342 or the focal points of the incident surface 129 of layer 128 forward in the direction toward the source of incident light relative to the centers of curvature 340 of the beads 14 increases convergence of such light 320, 322 into the beads 14, and converges such light into the beads 14 nearer to the ideal angles for refraction of such light 320, 322 through the transmission apertures 34. This filter assembly is-
believed to exhibits transmittance of up to about 60 percent.

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[0039] The support layer 12 diffuses light emanating through transmission apertures 34 through different vertical and horizontal viewing angles relative to axis 30 normal to the viewing surface 18, as previously described with reference to Figure 3. Alternatively, the support layer 12 may comprise a thin film of such anisotropical dispersing material, as previously described with reference to Figure 3, disposed on a thick layer of transparent material (on either side) to form a composite support layer for improved sturdiness of the light filter 120. The support layer 12 is affixed to the thin transparent layer 15 which, in turn, is affixed to the surface 27 of the opaque absorbing binder layer 16, with the viewing surface 18 oriented toward the viewer (not shown).

[0040] The index of refraction of the beads **14** is preferably selected to be from 1x to 1.3x index of refraction of the conformal layer **128** for increasing transmission of image light into the beads **14**. Suitable materials for the conformal layer **128** include polymethylmethacrylate and thermoplastic polyurethane (TPU), and similar clear thermoplastic materials. For example, a conformal layer **128** with an index of refraction of about 1.5 can be fabricated for either of these two materials, and the beads **14** can be fabricated from glass or resinous material selected with an index of refraction in a range between about 1.5 and 1.94. The conformal layer **128** beneficially reduces the difference, or mis-match in indices of refraction encountered by light **320**, **322** at the interface with the incident surface **36** of the beads **14**. This increases the transmittance of the **beads-14 filter**. Gain control can also be provided, by controlling the thickness and/or selectively shaping the incident surface **129** of the conformal layer **128** in the manner described above. In an alternative embodiment of the present invention, a layer of anisotropic or asymmetrical light diffusing material of the type previously described herein with reference to layer **12** may be used to asymmetrically disperse the incident light over a greater angle along the horizontal axis than along the vertical axis.

[0041] One process of the present invention for making light filter **122** of the embodiment illustrated in Figure 8 uses an opaque absorbing binder such as thermoplastic resin uniformly mixed with a colorant such as carbon black, a plurality of light transmissive beads **14** each of radius R , and a thin layer **15** of transparent material having a uniform thickness selected between about $0.1R$ and $0.5R$, and a support layer **12** of anisotropically diffusing film **12**. The opaque absorbing binder is selected to have a viscous unset state and substantially rigid set state, and the thin transparent material in layer **15** is selected to have a deformable semi-viscous unset state and substantially rigid set state. The process includes depositing a layer of the opaque absorbing binder in the unset state on the thin transparent layer **15** which is disposed on the incident surface of

[Handwritten notes: 'Beads' and 'Incident Surfaces' with arrows pointing to the text]

the asymmetrical diffusing support layer to a total thickness above the support layer 12 that is about 0.3 to 0.8 R. The plurality of light transmissive beads 14 are arranged in a single layer array on the surface 19 of the opaque absorbing binder to then penetrate the plurality of light transmissive beads 14 into the layer of opaque absorbing binder 16 and through the thin layer 15 to the support transparent layer 12. The opaque binder layer 16 is then activated into the set state for supporting the light transmissive beads 14 in position with the transmission apertures 34 of the beads 14 in contact with the asymmetrical diffusing layer 12. A layer of light transmissive material 128 in the unset state is disposed on protruding surfaces 36 of the beads 14, pressure is applied to the layer of light transmissive material 128 to substantially conform the layer to the shapes of protruding portions of the beads 14 and laminate the conformal layer to the beads 14 and the opaque absorbing binder 19. The layer of light transmissive material 128 is activated into the set state in a conventional manner for binding the layer 128 to the beads 14.

Layering the opaque absorbing layer 16 and thin transparent layer 15 as illustrated and described herein assures that portions of the incident surfaces 36 of the beads 14 protrude from the opaque absorbing binder. The deformable semi-viscous state of the light transmissive layer beneficially allows the layer it to conform to the shapes of these protruding portions of the beads 14 and retain the shape of defined lenses 131 with centers of curvature forward of the centers of curvature of the beads 14. Radii of curvature of these lenses 131 can also be adjusted in this manner. This process may result in a non-uniform thickness in the layer 128 measured normally to the incident surfaces 36 of the beads 14. Alternatively, a small quantity of light transmissive material may be centrally deposited on upper crests of the protruding beads 14 prior to depositing the layer 128 of light transmissive material in the unset state on protruding incident surfaces 36 of the beads 14. The combined volumes of transparent materials on the incident surfaces 36 of the beads 14 migrate together under heat and/or pressure to form the diffusion lenses as previously described on the incident surfaces 36 of each bead 14.

[0042] In another embodiment of the present invention, the asymmetrical gain of the filter may be enhanced along one axis relative to another orthogonal axis using a structure as partially illustrated in Figure 9. Specifically, the sectional view of the filter illustrated in this figure (i.e., as a top sectional view) shows a layer 399 of prismatic ‘lenses’ 400 having planar or plateau faces 402 and faceted or angular sloped faces 404, 406 in iterative, contiguous orientations along, for example, the horizontal axis of the filter. In this embodiment, the layer 399 of prismatic ‘lenses’ is disposed to receive incident collimated light rays A, B from a light source (not shown). Rays A impinging upon the plateau faces 402 are transmitted through the layer without deviation, and the dispersion of light via the successive segments of the filter including a beaded layer proceeds as previously described. However, collimated light rays B impinging upon the sloped faces 404, 406 are deviated from the incident orientation (~~by as much as about 20°~~) to provide additional dispersion through the successive segments of the filter including a beaded layer as previously described, with resultant wider viewing angle θ_2 along the horizontal axis. The horizontal angle may be adjusted by changing the size of the plateau faces 402 and the angles of the sloping faces 404, 406. It should be noted that enhanced viewing angle, for example, along the horizontal axis may be so enhanced with the prismatic layer 399 disposed before or after a beaded segment of the filter, and with the prismatic surfaces 402, 404, 406 facing in either direction relative to the axis of incident light. Also, the spacing shown between the prismatic layer 399 and beaded segment of filter on support layer 12 is illustrative only, and such spacing may be zero for a contiguous, layered structure.